The importance of conscious awareness for understanding sentences

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The Leverhulme Trust

Hugh Rabagliati
Alex Robertson
Dave Carmel

THE UNIVERSITY of EDINBURGH
School of Philosophy, Psychology
& Language Sciences

Demands on working memory.

the rabbit that Elmer Fudd wants

the lady that Elmer Fudd wants

Access to broader world knowledge

Reading and doing arithmetic nonconsciously

Asael Y. Sklar[a], Nir Levy[a,1], Ariel Goldstein[b,1], Roi Mandel[a], Anat Maril[a,b], and Ran R. Hassin[a,c,2]

[a]Psychology Department, [b]Cognitive Science Department, and [c]Center for the Study of Rationality, Hebrew University, Jerusalem 91905, Israel

Edited* by Michael I. Posner, University of Oregon, Eugene, OR, and approved October 5, 2012 (received for review July 12, 2012)

The modal view in the cognitive and neural sciences holds that consciousness is necessary for abstract, symbolic, and rule-following computations. Hence, semantic processing of multiple-word expressions, and performing of abstract mathematical computations, are widely believed to require consciousness. We report a series of experiments in which we show that multiple-word verbal expressions can be processed outside conscious awareness and that multistep, effortful arithmetic equations can be solved unconsciously. All experiments used Continuous Flash Suppression to render stimuli invisible for relatively long durations (up to 2,000 ms). Where appropriate, unawareness was verified using both objective and subjective measures. The results show that novel word combinations, in the form of expressions that contain semantic violations, become conscious before expressions that do not contain semantic violations, that the more negative a verbal expression is, the more quickly it becomes conscious, and that subliminal arithmetic equations prime their results. These findings call for a significant update of our view of conscious and unconscious processes.

nonconscious processes | automaticity | CFS

present set of experiments, we show that humans can semantically process subliminal multiple-word expressions and that they can nonconsciously solve effortful arithmetic equations.

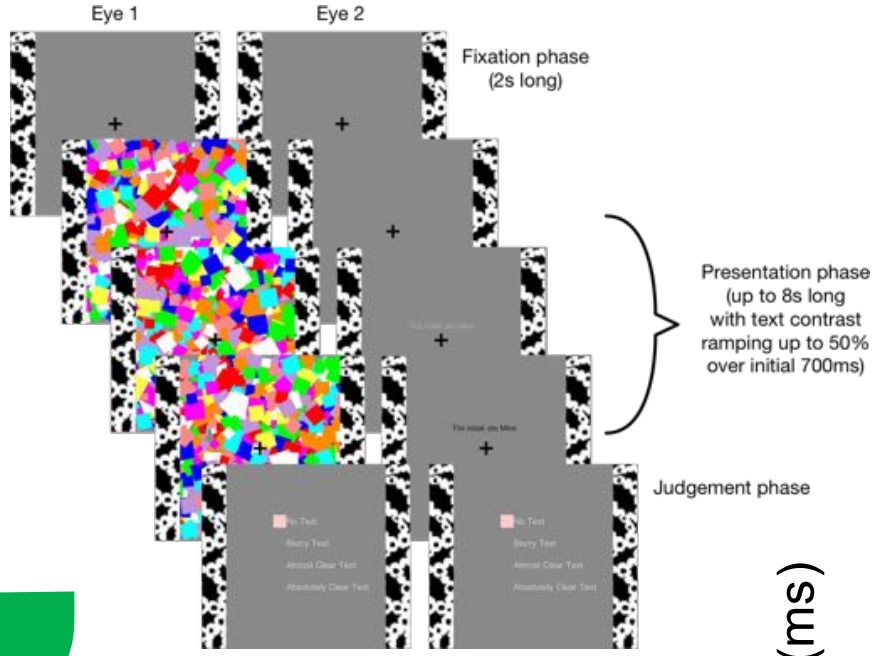
CFS consists of a presentation of a target stimulus to one eye and a simultaneous presentation of rapidly changing masks to the other eye. The rapidly changing masks dominate awareness until the target breaks into consciousness (Fig. 1) (17–19). Importantly, this suppression may last seconds (15). We used this technique in two different ways. In the first section, the critical dependent variable was the time that it took the stimuli to break suppression and pop into consciousness (popping time) (17). In the second section, we used masked expressions as primes and measured their influence on consequent judgments. Objective and subjective measures ensured unawareness of the primes.

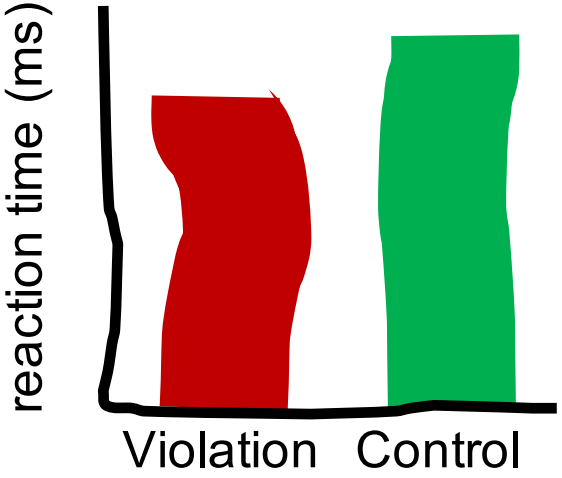
Results

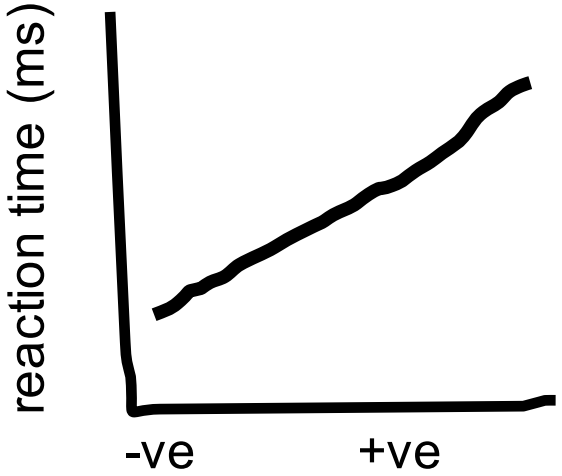
Reading. In all of the experiments in this section, we monocularly presented verbal expressions (e.g., black eye) masked by a series of Mondrian-like colorful shapes that were presented to the other eye. The task demanded that participants press a key as soon as verbal stimuli (e.g., a letter, a phoneme, or a word) break sup-

By Google Scholar, 120 citations (as of yesterday)

Breaking Continuous Flash Suppression







I ironed the coffee

I ironed the shirt

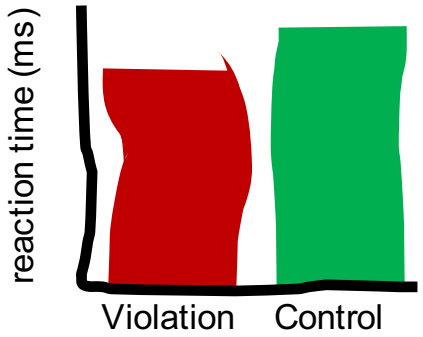
But in Hebrew.

stomach pump

paper clip

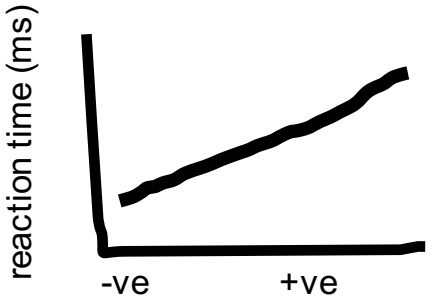
Unconscious understanding?

1. Do these results replicate in English?
2. Do they survive more stringent controls?



I ironed the coffee

I ironed the shirt



stomach pump

paper clip

Mike ate the steak

vs.

the steak ate Mike

the kitten chewed the lawnmower

vs.

the lawnmower chewed the kitten

Key takeaway

At least in English, we do not find reliable and robust evidence for unconscious combinatorial language processing.

Experiment 1

Expt 1a.

Replication of Sklar et al.'s Expt 1.

I ironed the coffee vs. *I ironed the shirt*

Expt 1b.

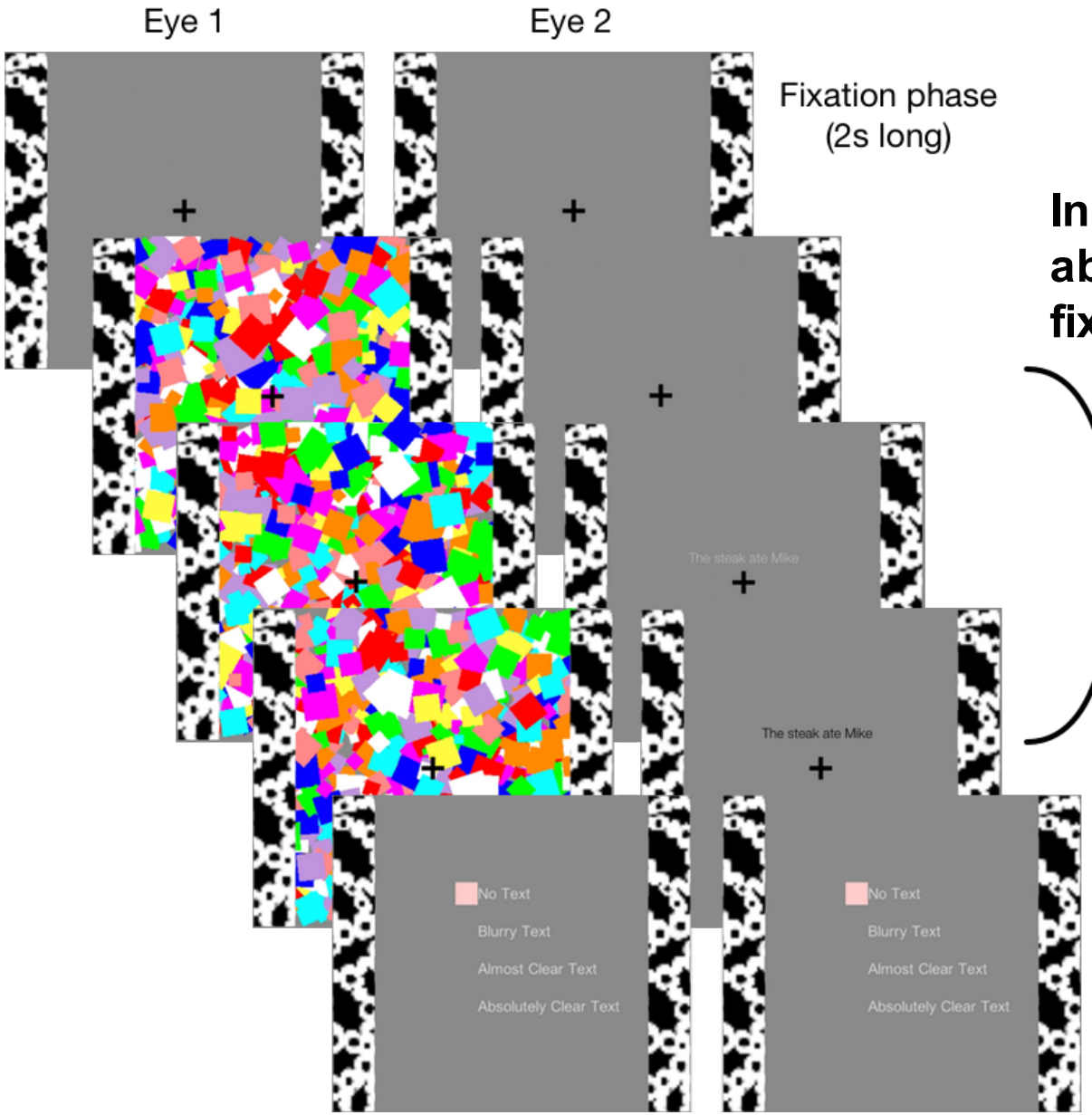
Reversible sentence extension of Sklar et al.'s Expt 1.

Mike ate the steak vs. *the steak ate Mike*

Sanity check.

Longer sentences break suppression faster.

Experiment 1



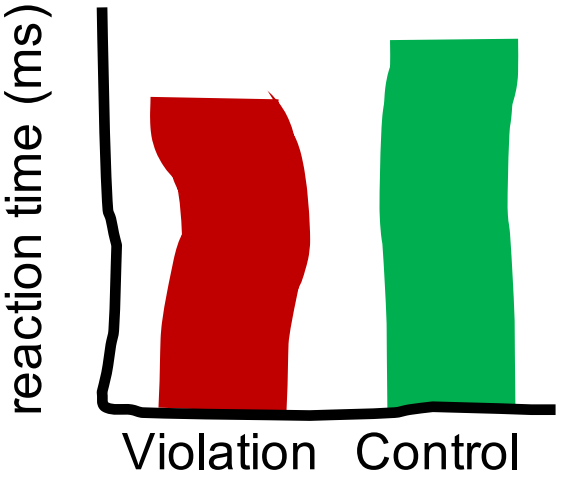
Experiment 1

- n = 53 (original n = 32)
- stimuli presented on 19” CRT, via mirror stereoscope.
- sentence stimulus ramped up from 0% to 50% contrast over 700ms.
- mondrians alternated at 60Hz.
- trials timed out after 8s.
- perceptual rating scale followed each trial

1a. Sklar Replication

- English translations of Sklar et al.'s original Hebrew stimuli.

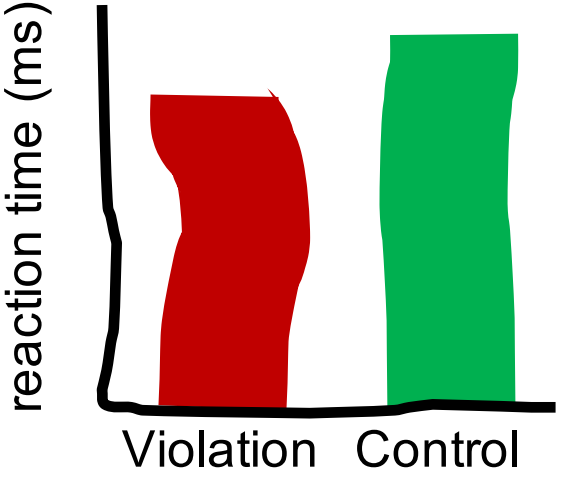
- 34 Violation Sentences:
  I ironed the coffee
- 68 Control Sentences:
  I made the coffee
  I ironed the clothes



1b. Reversible Sklar

- Short English sentences whose meaning was nonsensical in reverse order.

- 150 Violation Sentences:
  The steak ate Mike
- 150 Control Sentences:
  Mike ate the steak



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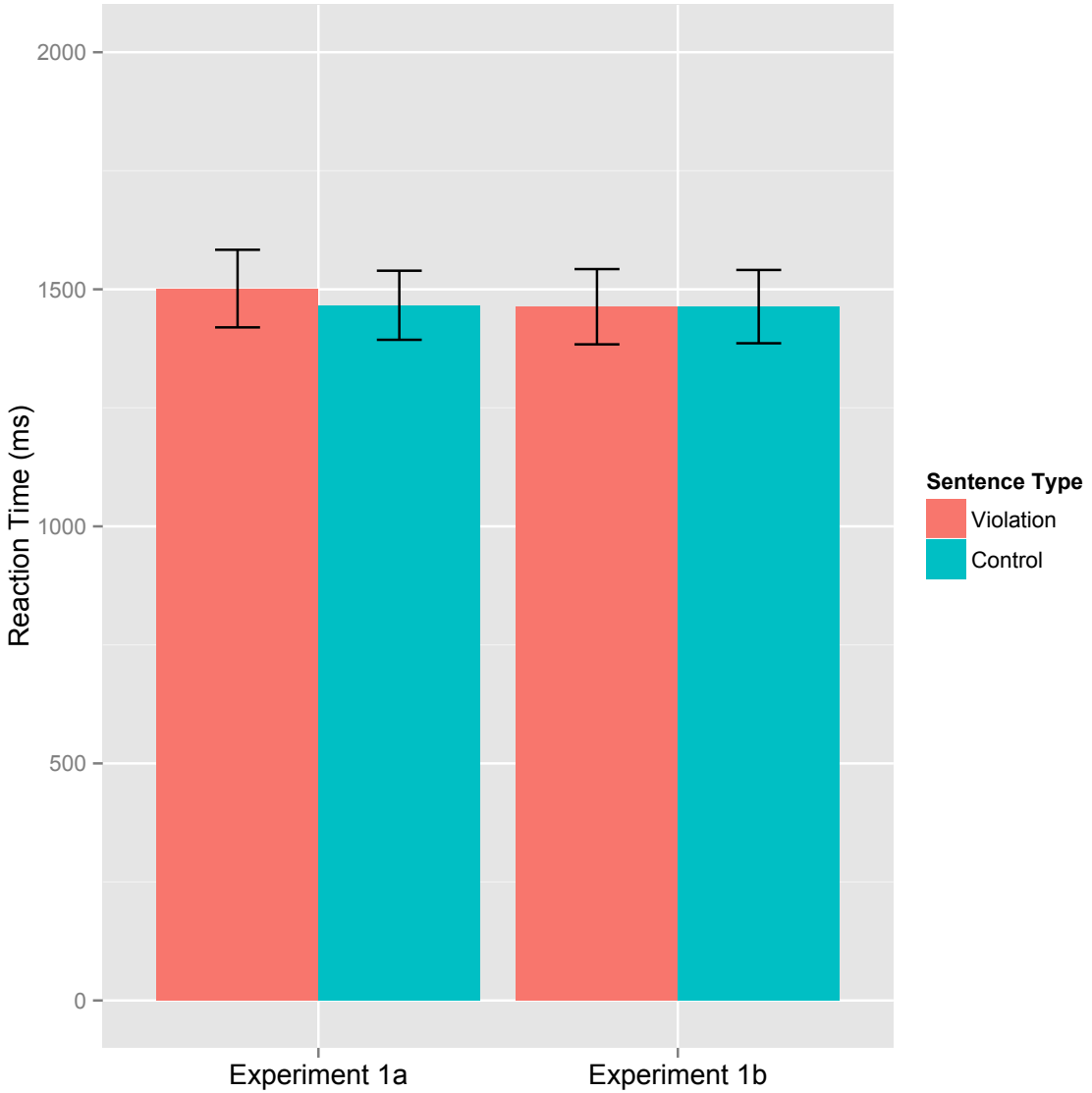
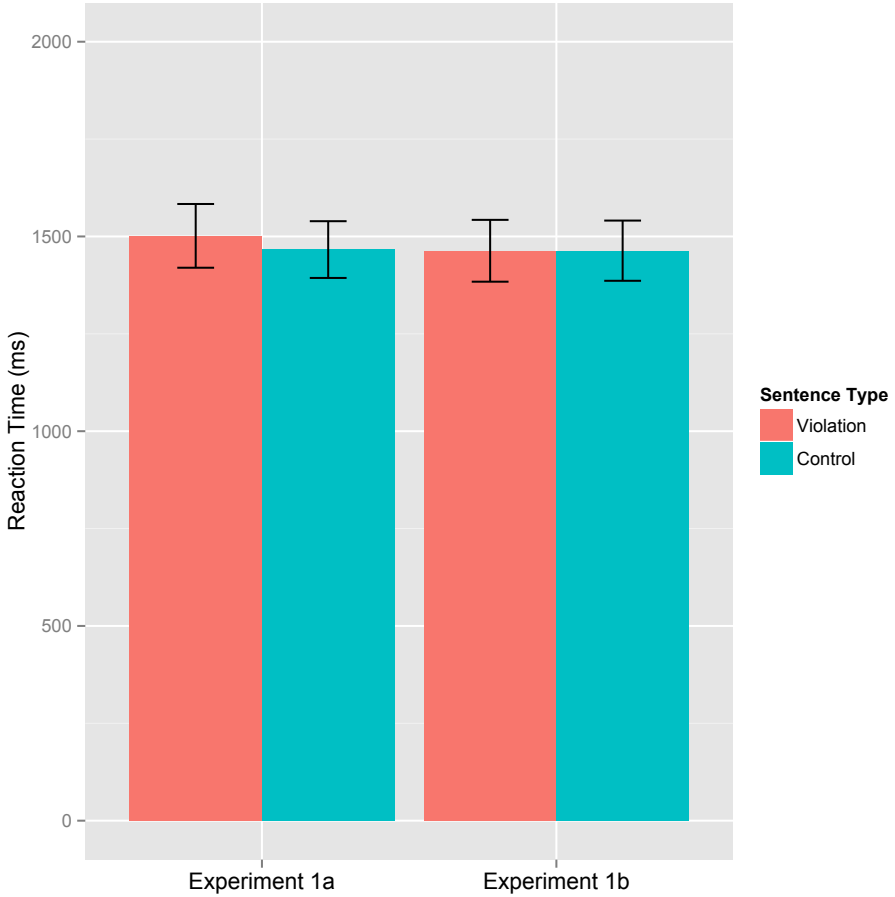


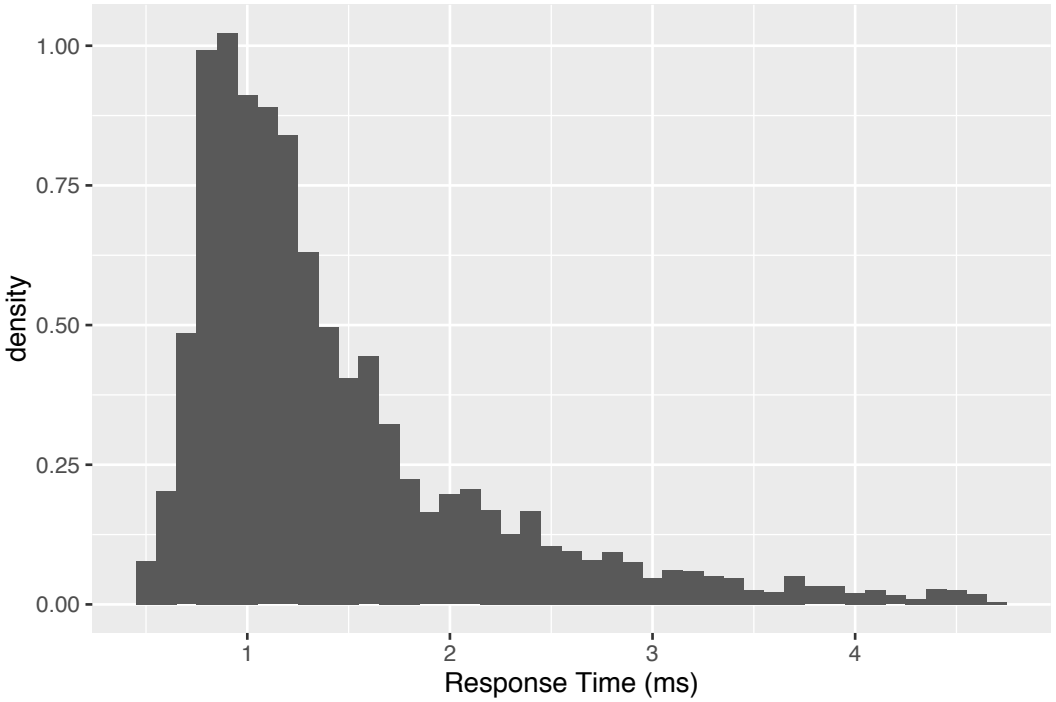
Raw reaction times:

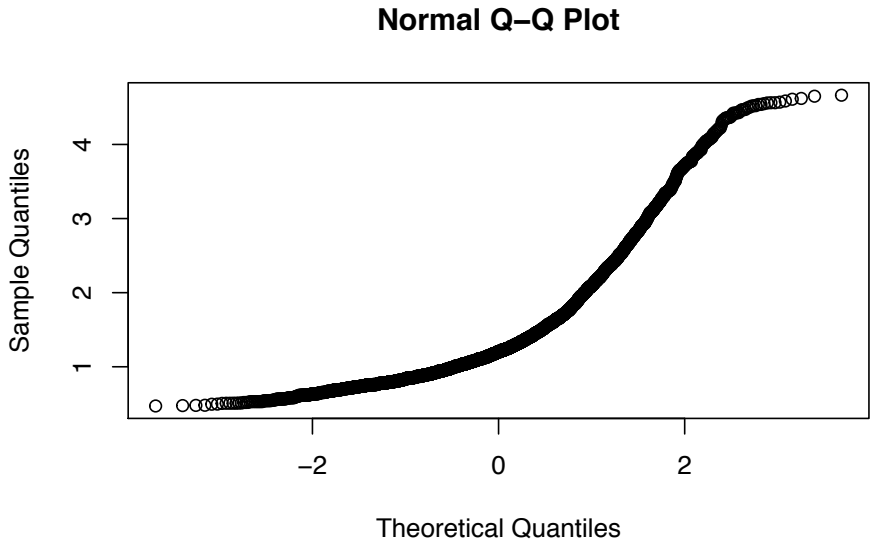
1a. Marg. Effect in wrong direction $t(47) = 1.79$, $p=.08$

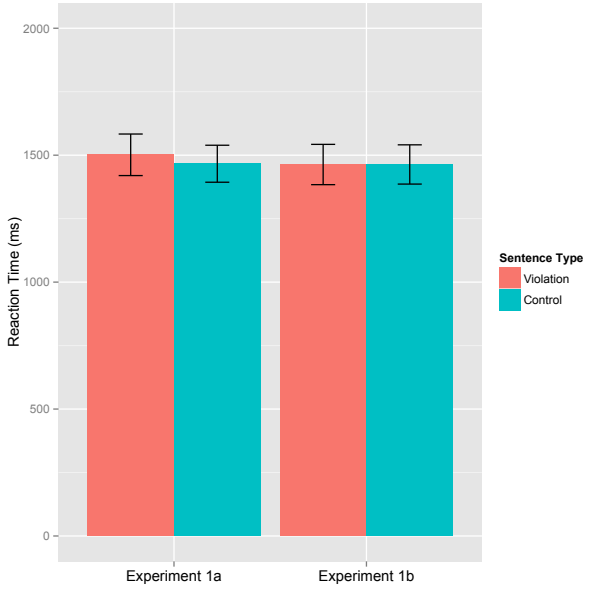
1b. No effect $t(47) = 0.02$, $p=.98$

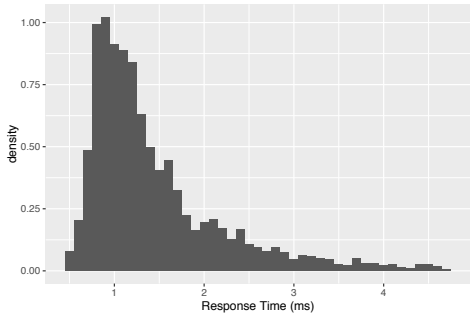
What lies beyond the bars?

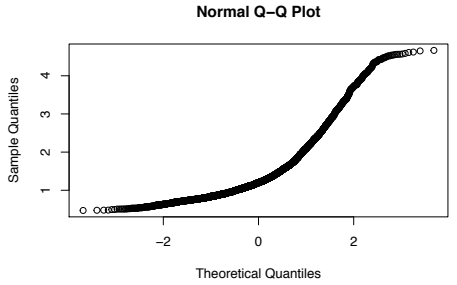




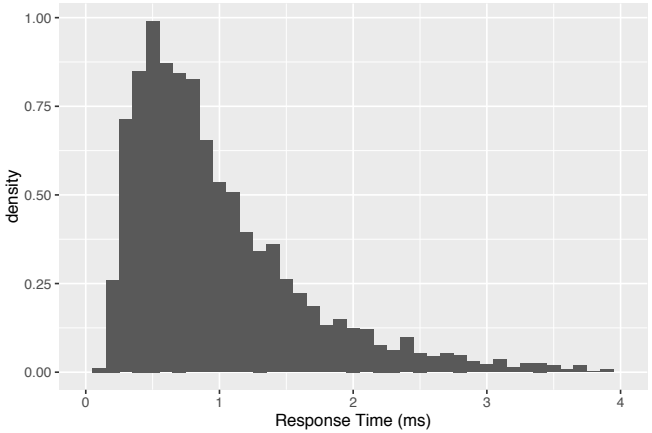








Mixed Effects Generalized Linear Model from **Inverse Gaussian** family



simulated Inverse Gaussian data

```
glmer(rt ~ Semantics + Length +
                (1+ Semantics| Subject) +
                        (1|Item),
                    family = inverse.gaussian)
```

1a. Sklar Replication

John ironed the coffee

No effect violation:
B=0.006, *t*=0.6, *p*=.52

Longer stims break faster
B=-0.024, *t*=3.4, *p*<.001

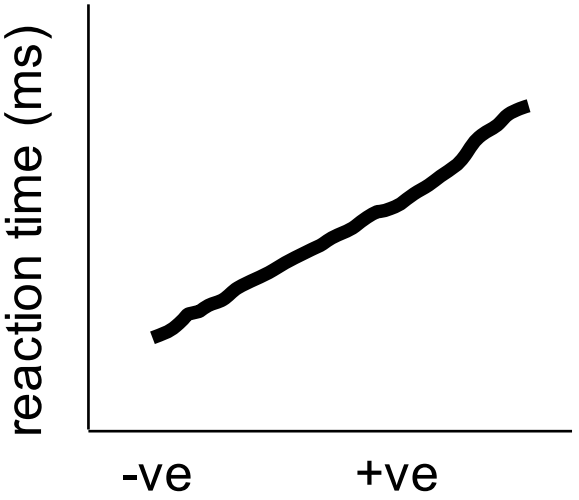
1b. Reversible Sklar

the steak ate Mark

No effect violation:
B=-0.002, *t*=0.4, *p*=.71

Longer stims break faster
B=-0.011, *t*=2.9, *p*<.01

Experiment 2



Expt 2a.

Replication of Sklar et al.'s Expt 4.

stomach pump vs. *hand rail*

Expt 2b.

Reversible Sentence Extension of Sklar et al.'s Expt 4.

the kitten chewed the lawnmower vs. *the lawnmower chewed the kitten*

Sanity check.

Longer sentences break suppression faster.

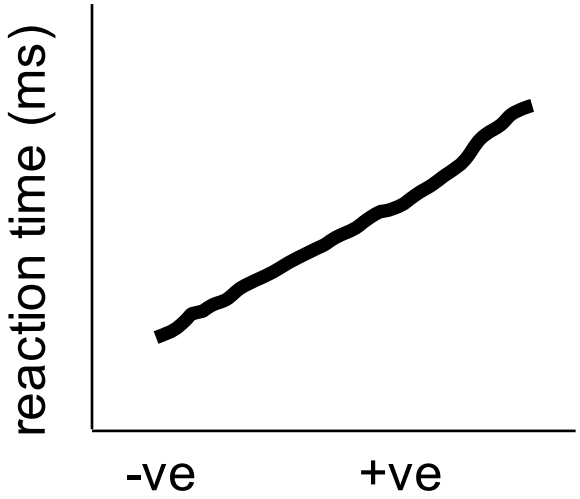
Experiment 2

- n = 73 (original n = 28)
- stimuli presented on 19” CRT, via mirror stereoscope.
- sentence stimulus ramped up from 0% to 50% contrast over 700ms.
- mondrians alternated at 60Hz.
- trials timed out after 8s.
- perceptual rating scale followed each trial

2a. Sklar Replication

- English translations of Sklar et al.'s original Hebrew stimuli, plus novel sentences.

- 50 sentences of varying affective ratings



2b. Reversible Sklar

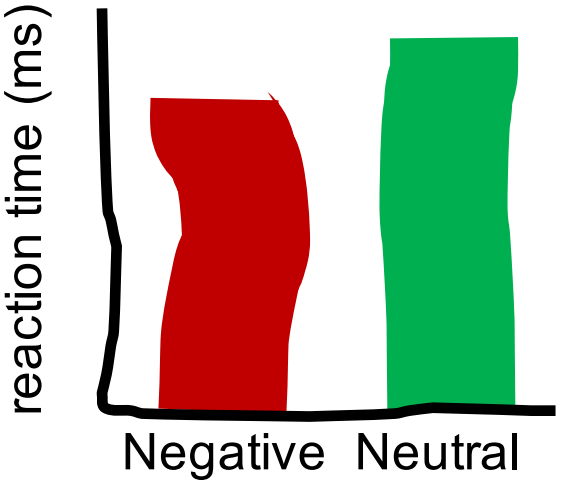
- Short English sentences whose meaning was neutral/negative depending on order.

- 28 Neutral Sentences:

the kitten chewed the lawnmower

- 28 Negative Sentences:

the lawnmower chewed the kitten



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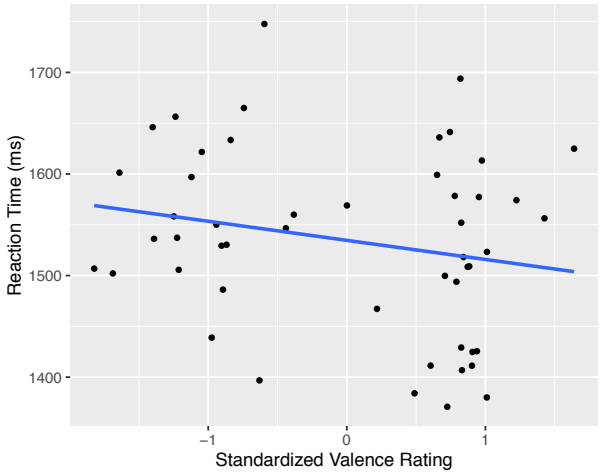


Semantics: B = -0.018, *t*=1.6, *p*=.10
Length: B = -0.018, *t*=2.2, *p*=.02

2b. Reversible Sklar

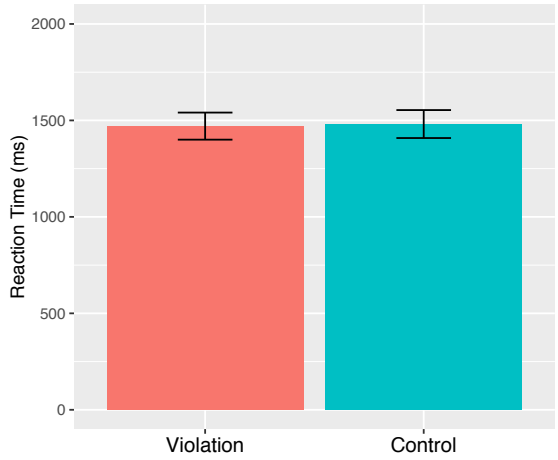
- Short English sentences whose meaning was neutral/negative depending on order.

- 28 Neutral Sentences:

the kitten chewed the lawnmower

- 28 Negative Sentences:

the lawnmower chewed the kitten



Semantics:
B = -0.002, *t*=0.2, *p*=.82
Length:
B = 0.018, *t*=2.7, *p*=.006

Summary so far…

Sklar et al. found…

Combinatorial analyses of suppressed sentences.

Semantically unusual sentences ***break suppression faster****.*

Our findings so far…

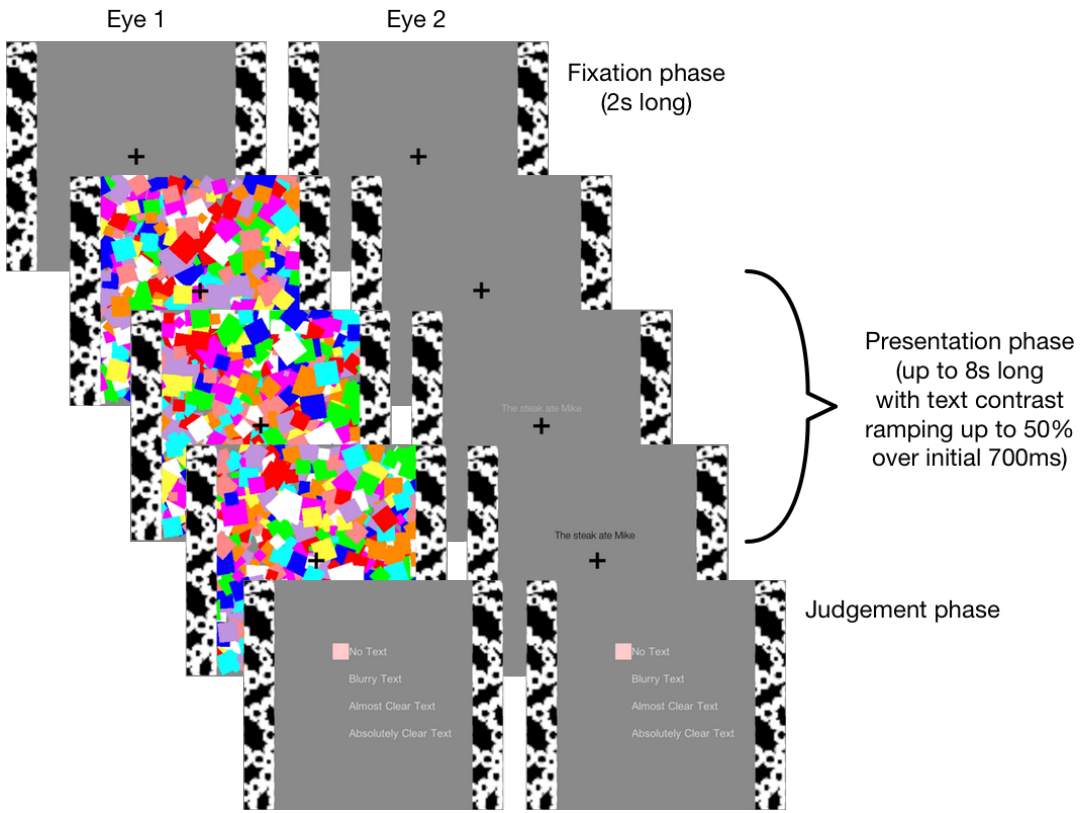
2 large datasets.

Replication studies: *Marginal effects in opposite direction – but not when analyzed with more appropriate stats.*

Extension studies: ***No effect*** *of semantics when surface features are controlled.*

Sanity check: *Longer stimuli* ***break suppression faster*****.**

How did our experiments differ?



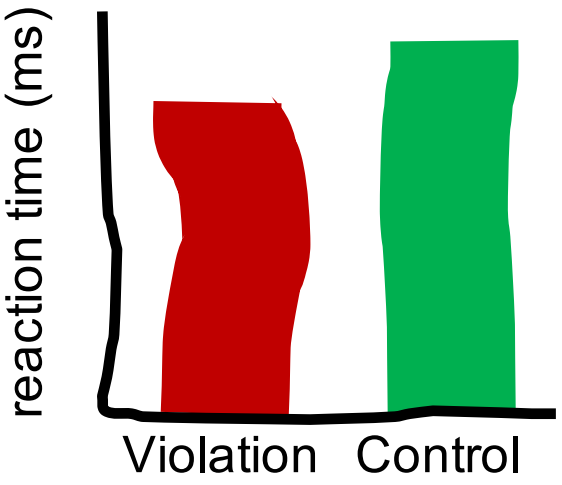
Re-ran all of our experiments using Sklar et al's original scripts (on English materials).

- mondrians alternated at 60Hz. → **10 Hz**
- trials timed out after 8s**.** → **20s**
- perceptual rating scale followed each trial. → **no PRS**

1a.-r Sklar Replication

- English translations of Sklar et al.'s original Hebrew stimuli.

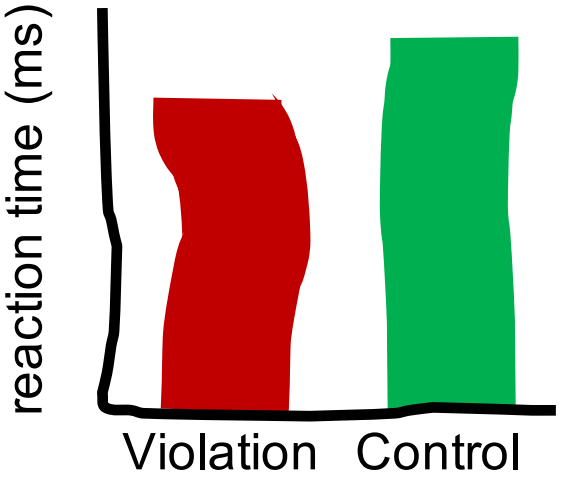
- 34 Violation Sentences:
  I ironed the coffee
- 68 Control Sentences:
  I made the coffee
  I ironed the clothes



1b.-r Reversible Sklar

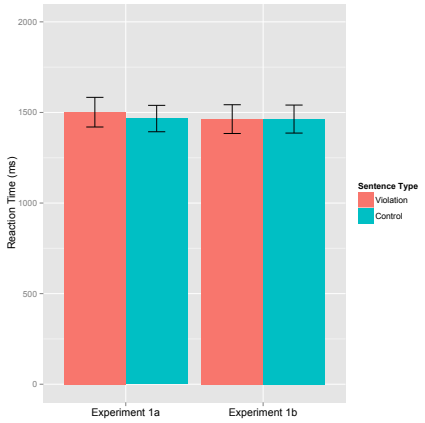
- Short English sentences whose meaning was nonsensical in reverse order.

- 150 Violation Sentences:
  The steak ate Mike
- 150 Control Sentences:
  Mike ate the steak



Experiment 1 replication

- n = 74 (original n = 32)
- stimuli presented on 19” CRT, via mirror stereoscope.
- sentence stimulus ramped up from 0% to 50% contrast over 700ms.
- mondrians alternated at 10Hz.
- trials timed out after 20s.
- No perceptual rating scale.

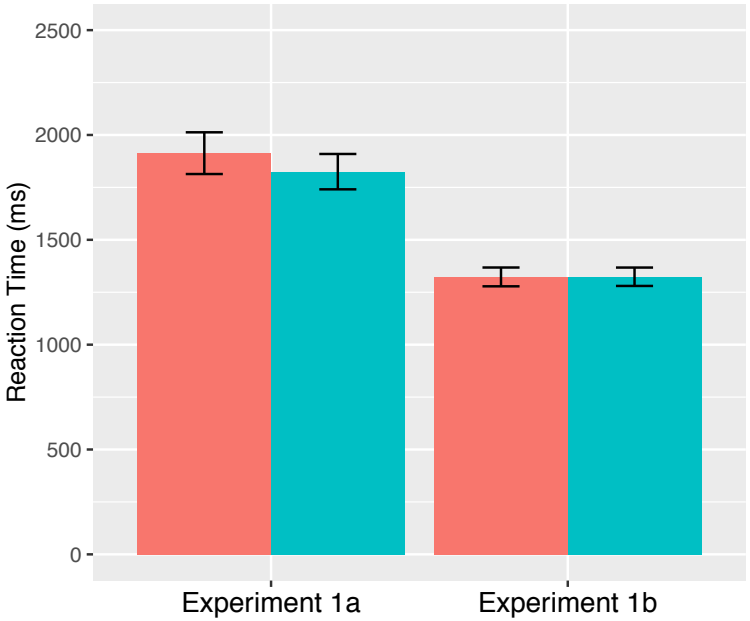


1a. Sklar Replication

No effect semantics
Longer stims break faster

1b. Reversible Sklar

No effect semantics
Longer stims break faster



1a-r. Sklar Replication

No effect semantics: B = 0.016, *t*=1.4, *p*=.17
Longer stims break faster: B = -0.024, *t*=2.8, *p*<.01

1b-r. Reversible Sklar

No effect semantics: B = 0.0008, *t*=0.15, *p*=.88
Longer stims break faster: B = -0.016, *t*=4.2, *p*<.001

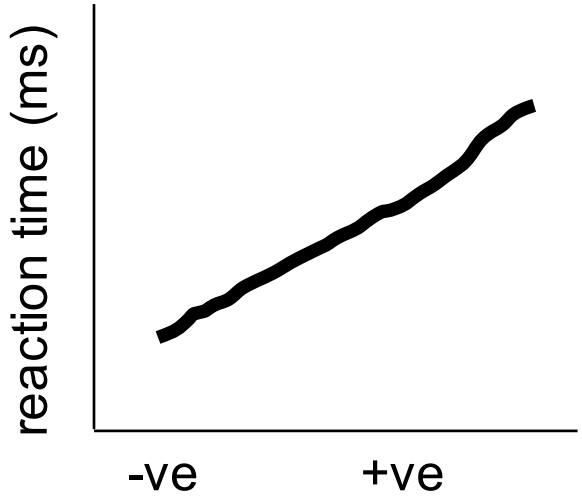
Emotional Experiment 2 replication

- n = 74 (original n = 32)
- stimuli presented on 19” CRT, via mirror stereoscope.
- sentence stimulus ramped up from 0% to 50% contrast over 700ms.
- mondrians alternated at 10Hz.
- trials timed out after 20s.
- No perceptual rating scale.

2a.-r Sklar Replication

- English translations of Sklar et al.'s original Hebrew stimuli, plus novel sentences.

- 50 sentences of varying affective ratings (e.g., *stomach pump*)



2b.-r Reversible Sklar

- Short English sentences whose meaning was neutral/negative depending on order.

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the kitten chewed the lawnmower

- 28 Negative Sentences:

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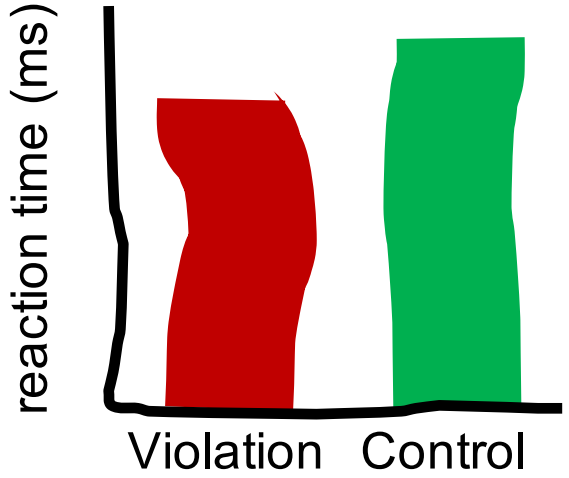
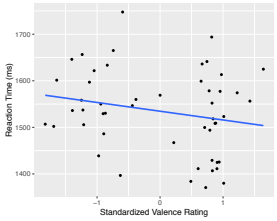


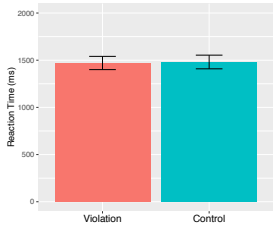
2a. Sklar Replication

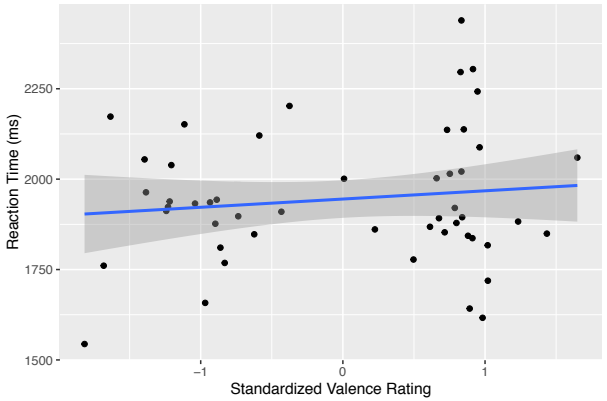
No effect emotion
Longer stims break faster



2b. Reversible Sklar

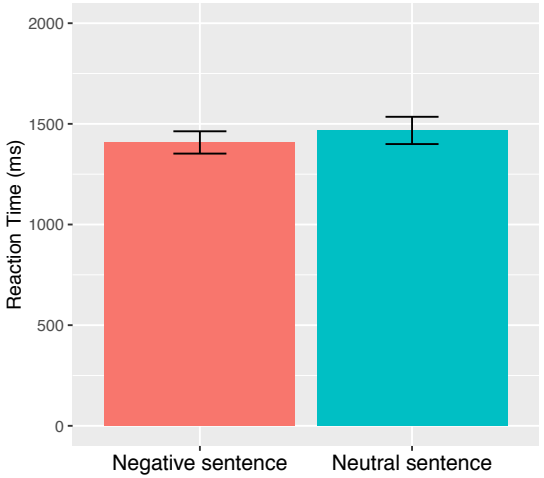
No effect emotion
Longer stims break slower (!)





2a-r. Sklar Replication

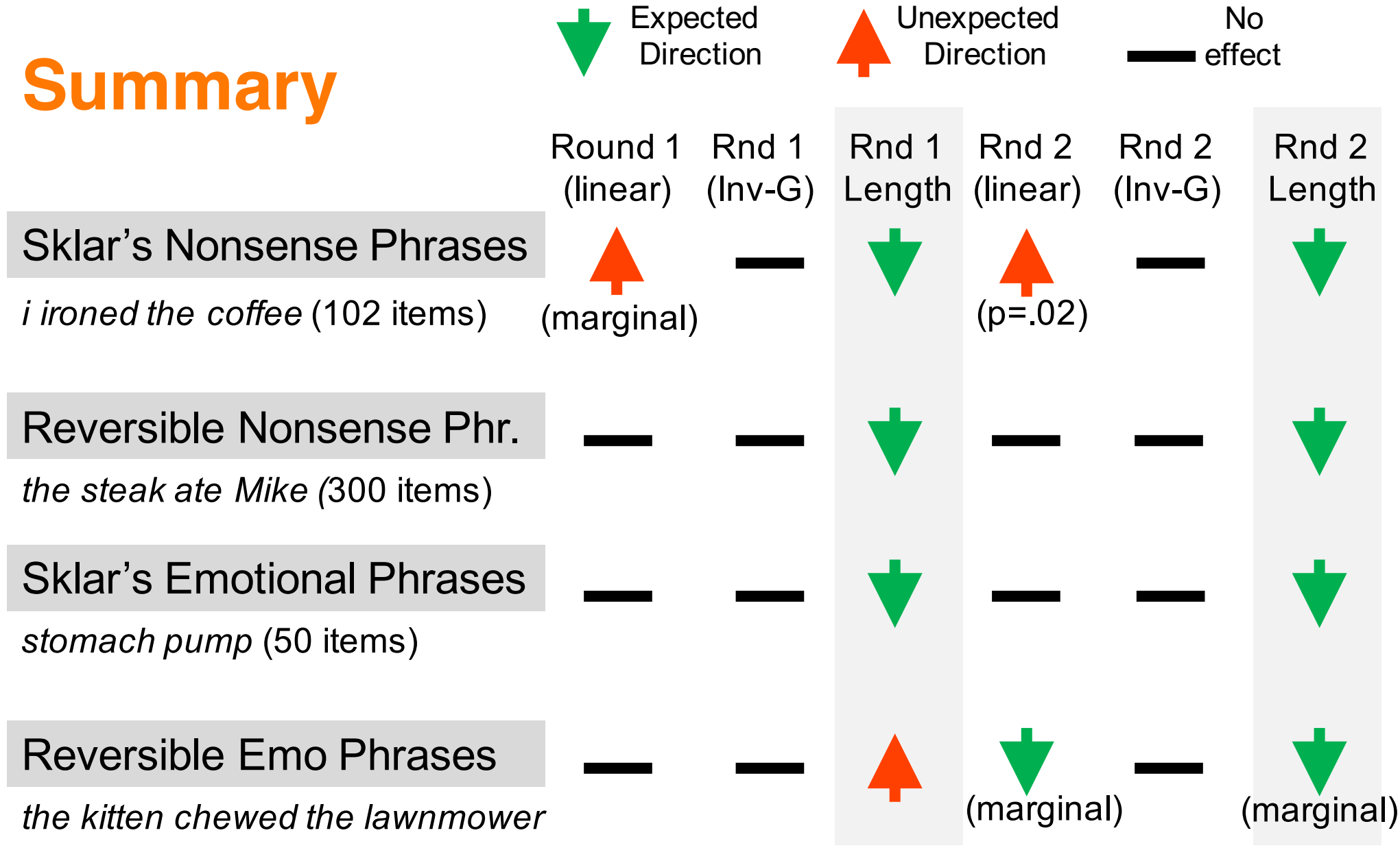
No effect emotion: B = 0.007, *t*=0.4, *p*=.66
Longer stims break faster: B = -0.04, *t*=3.7, *p*<.001



2b-r. Reversible Sklar

No effect emotion: B = 0.016, *t*=0.99, *p*=.32
Longer stims break marg. faster: B = -0.019, *t*=1.7, *p*=.08

Summary

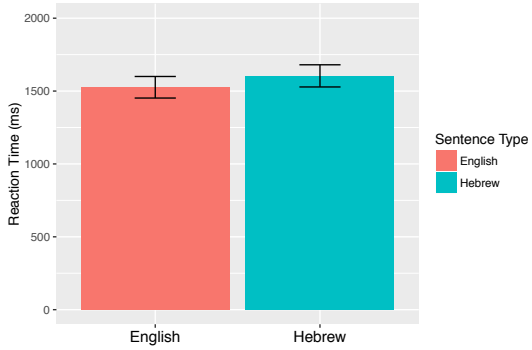


1. **No robust evidence for unconscious interpretation.**
2. **Marginal effects for low n conditions, when using ill-suited analysis methods.**
3. **Low power b-CFS effects are highly unstable.**

What sort of information is extracted during CFS?

High-level Semantics? No. Null effects across 8 experiments.

Mid-level?



For English speakers, English sentences break suppression faster than Hebrew sentences, replicating Jiang et al (2007).
B=0.06, *t*=4.2, p < .001

Lower-level visual information? Yes. Significant effects of length in 6 experiments, 1 marginal effect, and 1 effect in the wrong direction.

the rabbit that Elmer Fudd wants

Demands on working memory.

the rabbit that Elmer Fudd wants

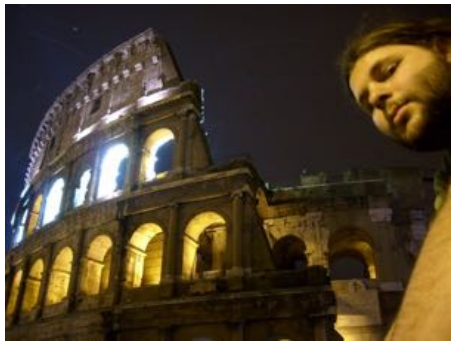
the lady that Elmer Fudd wants

Access to broader world knowledge

Many thanks to:

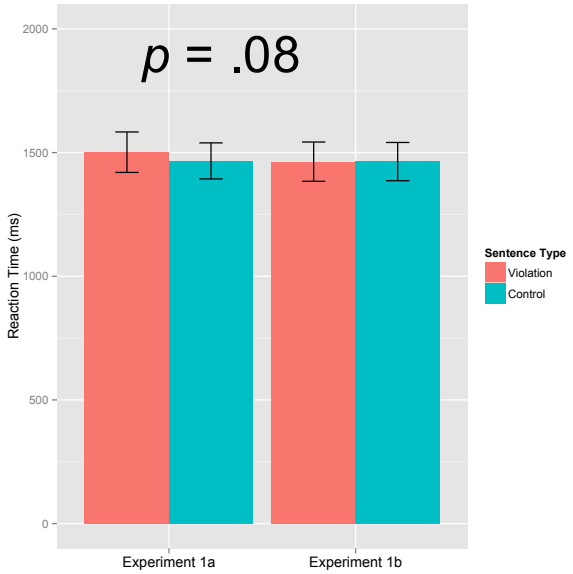
Ran Hassin

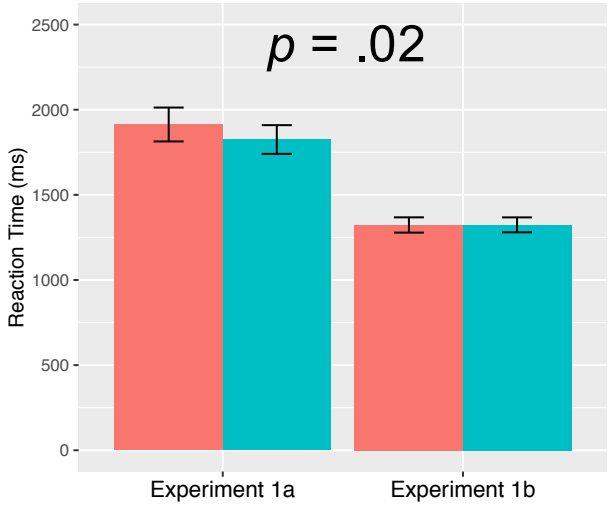
Asael Sklar



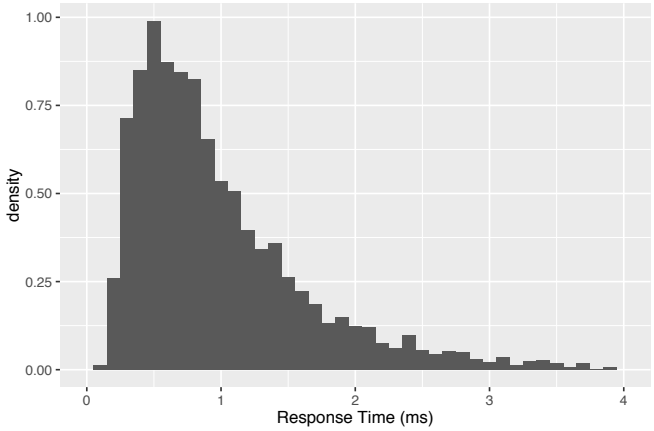
Ariel Goldstein

What is driving Sklar's nonsense phrase effect?





- 34 Violation Sentences:
  I ironed the coffee
- 68 Control Sentences:
  I made the coffee



Simulated 1000 null experiments using skew *t* distribution.

Applied Sklar et al's exclusion criteria.

False positive rate ~ 0.15 (1 in 7 chance of a significant result).

Almost 1 in 4 chance of a marginal result.

Are RTs still skewed when averaged?

Yes.